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PRINCIPAL INVESTIGATOR: Robert R. Whitecotton

CONTRACTING ORGANIZATION: Apple Computer, Inc.
Reston, Virginia 22091-4359

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13. ABSTRACT *(Maximum 200 words)*

The results of Project ProMED clearly demonstrated the potential usefulness of Personal Digital Assistants (PDAs), in particular, Apple's Newton MessagePad, in the health care environment of military medical centers. ProMED proved that PDA technology provides value in the clinical/medical computing environment, when used as (a) a personal productivity tool, (b) a wireless communicator for mobile practitioners, and (c) an interactive patient care information delivery resource. Health care providers adapted easily to the health care applications on the Newton MessagePad because of the natural graphical user interface (GUI) designed by the developer, KPMG Peat Marwick. The ProMED software solutions replaced cumbersome, paper-laden processes and allowed practitioners to practice medicine in a more natural, behavioristic way. On-line, real time access to important clinical and financial information provides the basis for the physician and other health care providers to provide quality, cost-efficient patient care. Clearly, though, Project ProMED illustrated that the long-term value of this type of technology in health care lies in its mobile communications capabilities and the ability to dynamically interact with the enterprise system and electronic medical record repository.

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1 Introduction

1.1 Background/Nature of the Problem/Previous Work

In June of 1992, Apple Computer Inc. was invited to meet with Mr. Paul Strassman, Deputy Assistant Secretary for Information Systems for the Department of Defense. Mr. Strassman, representing the Defense Information Systems Agency (DISA), proposed several project areas in which the Department of Defense would like to apply "Personal Digital Assistant (PDA) - type" technology. Dr. David Nagel of Apple Computer agreed to (1) review the projects, (2) make an assessment of Apple's technical capabilities in these areas, and (3) explore the viability of a concept demonstration and validation of Apple's technologies in the proposed project areas. Later, in October of 1992, Mr. John Sculley (CEO, Apple Computer Inc.) met with Mr. Strassman and reiterated Apple's commitment to examine the feasibility of cooperative "proof of concept" projects in the area of PDA technology.

One of the proposed projects that emerged from the initial meetings was ProMED, based on Apple's Newton technologies applied to medical applications in the DoD health care system. Four years in development, Newton is a sophisticated set of software and hardware technologies which will result in whole new classes of intelligent products. In effect, Newton technology is revolutionary and without precedent in the way it will support and process information. Key characteristics of these emerging Newton products will be mobility, communications, ease-of-use, and affordability. A more discerning characteristic of the Newton technology is its capabilities to provide intelligent assistance as it adapts to the user's particular style of operating. In this way, over time, the product can become more personal and more helpful.

ProMED, with its focus on health care practices, will provide a fertile test bed for PDA/Newton technologies. This can be better understood by examining the major inefficiencies in health care environments today. These include:

- Lag in turnaround time from test request to results reporting
- Incomplete documentation because of a cumbersome, paper-focused process
- Lag time between when patient events occur and when they are documented
- Phone time to relay results and other significant clinical data to care providers
- Delays in the delivery of patient care, because the chart or results are inaccessible
- Time to reconcile written physician orders
- Transcription errors.

The reasons why these inefficiencies exist even in highly automated health care settings are: low physician utilization of systems, station and terminal access constraints, and a continued dependence on the paper medical record.

The promise of PDA technology provides the opportunity to overcome these barriers.

1.2 Purpose of the Present Work/Project Objectives

Apple Computer, Inc. with its partner KPMG Peat Marwick was directed to conduct a prototype study with the Department of Defense (DoD) to investigate the concept of PDA suitability in the DoD health care environment. The intent was to deploy a series of Newton devices to the health care providers in targeted departments of three DoD health care test sites, namely (1) Vascular Surgery department - Walter Reed Army Medical Center, (2) OB/GYN department - Wright-Patterson Medical Center, and (3) Troop Medical Clinic - Brooke Army Medical Center. In an iterative fashion, core Newton and peripheral technologies were fielded to demonstrate and validate their unique and powerful capabilities. Specific focus was on identifying the productivity and cost savings potential of PDA technologies in the DoD health care community and to discuss possible changes in the health care processes required to effectively employ the emerging technologies. A secondary focus was to examine both the capabilities and limitations of the PDA technologies themselves in order to identify future required technology developments related specifically to DoD health care operations.

The overall project objective was the concept exploration and validation of PDA technologies for medical applications within the Department of Defense. Within this objective, specific targets investigated included:

- Plausible application areas and associated productivity/cost savings potential for PDA technologies within DoD health care operations.
- Possible changes in health care processes required to effectively employ emerging PDA technologies.
- Capabilities and limitations of PDA technologies themselves as represented by the Apple Newton products to include technical specifications.
- Further technology developments, if any, required to 1) address any limitations of PDA technologies and/or 2) assure successful deployment of PDA technologies.

From the perspective of overall military significance, ProMED provides a strategic learning laboratory for new DoD health care delivery models, with particular emphasis on process redesign through emerging automation and communications technologies. These technologies characterized by their mobility, connectivity, ease-of-use, and affordability promise to be the next generation of electronic productivity support tools.

Suggested ProMED applications offer possible productivity enhancements and cost savings in such areas as clinical documentation, ordering/diagnostics, prescriptions, results notification, reference materials, and provider to provider communications.

It is important to emphasize the overall project objective which is the concept exploration and validation of PDA technologies for medical applications within the Department of Defense. In this context, a key significance is to capture and disseminate the project experience within the DoD health care community to help define PDA technical requirements and standards for future procurements.

1.3 Methods of Approach

KPMG Peat Marwick (subcontractor) participated with Apple Computer in the study to investigate the concept of PDA suitability in the DoD health care environment.

KPMG Peat Marwick provided proprietary baseline templates for clinical system functional requirements and employed a proprietary System Development Life Cycle methodology in the conduct of the study. Also, a development and implementation technique referred to as Rapid Application Development (RAD) was used to support the highly iterative development and deployment process

Specifically, in conjunction with Apple, KPMG's application specialists and technologists:

- Defined the functional requirements for medical applications appropriate for PDA devices.
- Designed and developed application prototypes.
- Evaluated local and remote communications alternatives.
- Investigated technology to integrate Newton with enterprise systems in the future.
- Provided end-user training to study participants
- Provided on-site support during the implementation of medical application prototypes.
- Assisted each DoD test site in identifying and documenting the benefits resulting from the use of PDA technology.

Actual work activity was conducted, sequentially, in three phases, namely (1) Concept Introduction, (2) Concept Demonstration, and (3) Concept Validation.

As this process was one of discovery and iterative development, actual deployment of technologies and applications may vary from the original content as described below. Also, development and deployment timetables changed slightly depending upon availability of equipment, materials and resources. Any revision to dates were mutually discussed and agreed to by all participants.

Phase 1 - Concept Introduction

A. Advance seeding of 3-5 Newtons to senior DoD health care officials.

Goal: Early acquaintance of DoD health care policy makers with Newton technology.

B. Establish structure of test site environment by: 1. Initiating project at each site (establish organization, identify participants, set up monitoring mechanisms), 2. Providing technology introduction/training, 3. Documenting the current business

processes (establish current baseline), 4. Introducing project vision to participants, 5. Preparing site for delivery, 6. Deploying 45-75 Newton MessagePads to selected physicians across the three selected sites (Walter Reed Army Medical Center, Wright-Patterson Medical Center, and Brooke Army Medical Center) and 7. Providing Newton training to selected participants.

Goal: Establish operational baselines, obtain general familiarity of participants with the Newton product as a personal productivity tool, gain participant acceptance of the product, and establish competent participant user skill level.

Phase 2 - Concept Demonstration

A. ProMED preliminary concept demonstration - introductory use of Newton as a medical productivity aid. Introduce additional operational capabilities according to the following methodology (perform sequence for each new capability): Identify/measure benefit targets, perform rapid prototype development, validate design at sites, train users on new capabilities, assess effectiveness, and develop interim reports.

Goal: Gain operational experience in medical environment, evaluate use of Newton paging/messaging technology in medical operations, assess initial application of an on-line medical form, and evaluate application development tools.

B. Increased use of Newton in the medical environment with emphasis on inpatient rounds; initial use of Newton for prescriptions, laboratory requests, and radiology appointments with limited data entry checking. Establish Macintosh server docking station(s) for Newton.

Goal: Identification of technology requirements in support of data entry validation and understanding of docking and data transfer procedures.

Phase 3 - Concept Validation

A. Development of Newton's untethered communications capabilities targeted toward real-time data collection and transfer as applied to reference information, pharmacy prescriptions and laboratory tests, and augmented use of new Newton form factors.

Goal: Evaluate technical and operational capabilities for wireless communications such as diffuse IR or an equivalent alternative and analyze Macintosh server requirements for bridging Newtons to enterprise systems.

B. Limited operational test with metric collection. Document and evaluate project findings.

Goal: Demonstrate potential productivity gains in DoD health care via use of Newton technology and record and disseminate "lessons learned" from ProMED project.

2 Body

2.1 Major Activities, Activity Timeline (Actual)

26 October 1993	Project Kick-off Meeting,
November 1993	BAMC Project Kick-off Meeting, Newton MessagePad Distribution, Phase 1 User Training
	WRAMC Project Kick-off Meeting, Newton MessagePad Distribution, Phase 1 User Training
	Wright-Patterson Kick-off Meeting, Newton MessagePad Distribution, Phase 1 User Training
16 December 1993	Project Status Meeting, Ft. Detrick
19-20 January 1994	ProMED Site Champion Meeting, San Antonio
February 1994	Wright-Patterson Project Review/CHCS IF Meeting
10 March 1994	Project Review Meeting with LTC Dean Calcagni
September 1994	Phase 2 Live; Wright-Patterson (WP), Walter Reed Army Medical Center (WRAMC)
November 1994	CHCS/ProMED Interface Live; WP
May 1995	Phase 3 Live, without Wireless; WRAMC
June 1995	Phase 3 Live, with Wireless; WP
July 1995	Phases 2 & 3 Live, with Wireless; Brooke Army Medical Center (BAMC)
August 1995	Phase 3 Wireless & FileMaker Pro/Duplex Study Interface Live; WRAMC

Summary of Accomplishments (3/94)

General/User-Oriented

1. Conducted project kickoff meetings with site champions and introduced tentative workplan and schedule.
2. Completed pilot site walkthroughs of pertinent departments including ancillary areas, such as, laboratory, pharmacy, radiology, and the information system department.
3. Conducted multiple sessions of the Newton Boot Camp where users received basic training on Newton MessagePad functionality as well as a demonstration of the initial ProMED prototype.
4. Organized site-specific project management, conducted user focus groups, and documented process workflows for areas impacted by ProMED applications.

5. Reviewed management information needs and associated data requirements.

6. Compiled current forms, reports, order slips, and other documents having a potential impact from Newton ProMED applications.

7. Participated in inpatient rounds/outpatient encounters with providers for purpose of observation.

8. Conducted interviews with ancillary departments as part of the focus group activity for the purpose of documenting work processes related to interaction with the patient care areas.

9. Formulated and validated draft user requirements with pilot sites.

10. Discussed the impact of Newton ProMED on the use of the CHCS enterprise system at the two sites where it constituted a viable factor, namely: Walter Reed Army Medical Center and Wright-Patterson Medical Center.

11. Confirmed priorities for application software development with pilot sites.

12. Completed approximately 75% of the design for Phases 2 and 3 of the ProMED prototype.

13. Incorporated system requirements into appropriate Newton MessagePad views.

14. Documented statistical breakdown of workload volumes for pertinent patient care services at the various pilot sites. This included data for lab, pharmacy, and radiology orders as well as average patient census data and outpatient activity.

15. Consolidated user requirements from all three pilot sites and finalized a "storyboard" of the Phase 2 conceptual prototype which was to be delivered to the sites.

16. Initiated development of project evaluation metrics by developing a high-level data collection methodology.

17. In response to user requirements and following a consensus concerning development priorities, formulated a revised Phase 2 implementation workplan and schedule.

18. Began formulation of a detailed data dictionary which was required for the development and maintenance of a client-server network environment to support effective utilization of the Newton ProMED MessagePad at the pilot sites.

Technology/Development

1. Participated in Newton Boot Camp training at the pilot sites.

2. Inventoried existing technology at the pilot sites and established a technical baseline.

3. Developed preliminary site-specific technical requirements.

4. In preparation for the ProMED project kick-off, developed a prototype (v10/12) to demonstrate the potential use of health care applications on the Newton MessagePad and to stimulate ideas for the pilot application design.

5. Developed a functional prototype (v1.0d) to validate the ProMED architecture strategy and build a re-usable code base for Newton applications.

6. Defined a preliminary strategy for ProMED architecture development. This approach allows for sharing of objects between potential packages enabling packages to operate independently or with other packages of the same product family.

7. The following progress was made toward developing an Apple Newton™ communications server architecture:

   - ADSP connection between Newton and Macintosh Communications Gateway was in development.
   - Newton-to-Server protocol and software architecture. The protocol was defined, the architecture was defined, and messaging design was in-progress.
   - Newton download. Software to download data to Newton was in process of being designed and developed.
   - Investigated peer-to-peer messaging.

Summary of Accomplishments (9/94)

General/User-Oriented

1. Finalized site-specific process workflows for areas impacted by Newton applications.

2. Delivered the Phase 2 conceptual prototype , trained site participants, and solicited feedback on its design.

3. Finalized Phase 2 user requirements and Phase 2 scope with pilot sites.

4. Finalized the functional requirements for Phase 2 and distributed the document to the pilot sites. This also included designs for potential Phase 3 applications.

5. Completed design of the Phase 2 data model and detailed data dictionaries required for the development and maintenance of the client-server network environment which is fundamental to the effective utilization of the Newton MessagePad at the pilot sites.

6. Revised the Phase 2 implementation workplan to reflect changes in the development schedule and the level of preparedness of the pilot sites to implement the Phase 2 applications.

7. Completed design and development activity for Phase 2 Newton software applications, including (a) patient census, (b) patient demographics, (c) laboratory orders, (d) pharmacy orders, and (e) imaging orders. This functionality was completed, tested, and ready for installation .

8. Completed design and development activity for Phase 2 ProMED Admin Server software applications, including (a) provider management and (b) patient management. This functionality was completed, tested, and ready for installation.

9. Continued discussion of the impact of Newton on the CHCS enterprise system at the two sites where it constituted a viable factor, namely: Walter Reed Army Medical Center and Wright-Patterson Medical Center.

10. Completed approximately 80% of the design for Phase 3 of the ProMED pilot.

11. Continued to investigate the best means for documenting and evaluating project findings. Discussed methods for measuring success with the pilot sites.

12. Continued the discussion to refine the Phase 3 scope in light of the progress made to date, the impact on resources, and the limited availability of commercial connectivity products required for client/server based Newton communications (including the wireless component).

13. Developed and introduced an incident reporting methodology to the pilot sites.

14. Investigated the availability of baseline evaluation statistics.

Technology/Development

1. Recommended initial equipment requirements to implement the first delivery of Phase 2 functionality, i.e., paging via Newton Message cards, preparing to implement.

2. Finalized the user interface design for the Phase 2 Newton components of the system. Completed development of Newton components for Phase 2 applications.

3. Designed and developed the communications architecture to support the ProMED applications. This included the communications gateway, ProMED Newton communications architecture, Newton-to-Server protocol, software architecture, and database services.

4. Completed a version of the ProMED server designed to meet the Phase 2 requirements. The server had been designed to support expanded functionality for Phase 3 and subsequent phases of the project. Development of the server included the design and development of the CommGate, ADSP to TCP protocol converter required for the Newton, Newton to server communications, communications services, database services, and the installation and configuration of the Oracle database.

5. Designed and developed database access routines required for Phase 2 functionality.

6. Determined and recommended technical requirements for Phase 2 pilot deployment at each site, i.e., equipment list.

7. Investigated wireless technologies and tested for fit within the architectural approach of the ProMED server, i.e., Digital Ocean.

Summary of Accomplishments (3/95)

General/User-Oriented

1. Continued testing and quality assurance of the Phase 2 deliverables to ensure implementation readiness once the pilot sites were ready of implementation.

2. Finalized the scope, design, and development of Phase 3 applications in collaboration with the pilot sites under the direction of the project leader, Bob Whitecotton, Apple Computer. Phase 3 applications including wireless were ready for installation and implementation.

3. Incorporated user feedback into the Phase 2 and Phase 3 data model and detailed data dictionaries which are required for the development and maintenance of the client-server network supporting the effective utilization of the Newton MessagePad at the pilot sites.

4. Delivered and implemented the Phase 2 Newton software applications, trained users and activated the system for use at Walter Reed Army Medical Center and Wright-Patterson Medical Center.

5. Completed design of the Phase 2 and Phase 3 data model and detailed data dictionaries required for the development and maintenance of the client-server network environment which is fundamental to the effective utilization of the Newton MessagePad at the pilot sites.

6. Revised the Phase 2 implementation workplan to reflect changes in the development schedule and the level of preparedness of the pilot sites to implement the Phase 2 applications.

7. Delivered and implemented the Phase 2 ProMED AdminTool software applications, including (a) provider management and (b) patient management, trained users, and activated the system at Walter Reed Army Medical Center and Wright-Patterson Medical Center.

8. Continued discussion of the impact of Newton on the CHCS enterprise system at the two sites where it constituted a viable factor, namely: Walter Reed Army Medical Center and Wright-Patterson Medical Center.

9. Continued to investigate the best means for documenting and evaluating project findings. Discussed methods for measuring success with the pilot sites.

10. Conducted site status meetings either via conference calls or on-site to discuss progress and revised implementation schedules.

11. Following implementation and activation of Phase 2 applications, instituted system support protocols and procedures to support use of system at Walter Reed Army Medical Center and Wright-Patterson Medical Center.

12. Completed development of a comprehensive on-site testing methodology for use during implementation of Phase 2 and Phase 3 applications.

13. Implemented and activated a limited patient demographics CHCS/ProMED interface at Wright-Patterson Medical Center for the purpose of automatically receiving extracted demographic information for specific patients scheduled for visits to the OB/GYN clinic.

14. Completed development of a Phase 3 Implementation Workplan and Phase 3 System Test Plan.

Technology/Development

1. Performed installation of Phase 2 applications and system components including, Newton client applications, Newton/Server communications, ProMED server, ProMED database, and AdminTool.

2. Designed, developed, and installed patient demographics CHCS/ProMED interface for use at Wright-Patterson Medical Center.

3. Finalized the application scope and Newton user interface design for Phase 3. Completed development of Phase 3 applications including Newton client applications, database and communication services, and administration and reporting tools, i.e. orders output. Oracle Reports was selected as the development tool for creation of the orders reporting/output.

4. Designed and developed additional system components to support the Carotid Artery Duplex Study functionality recently required for WRAMC including, ProMED/FileMaker Pro interface for patient data, Newton client application design and development, and database services.

5. Completed development of the ProMED server to meet the Phase 3 requirements noted above. Development of the server included the design and development of the CommGate, ADSP to TCP protocol converter required for the Newton to Newton server communications, communications services, database services, and the installation and configuration of the Oracle database.

6. Tested the selected wireless technology solution, Digital Ocean, for Phase 3 deployment.

7. Conducted site assessment in preparation for deployment of wireless communications, defined equipment and facility requirements, and conveyed this information to both Apple and DoD.

2.2 Description of Required Deliverables (Actual Dates)

Phase 1

November 1993	Project introduction to each site
	ProMED Conceptual Prototype Overview, Release 1.0d (DoD)

Phase 2

March 1994	Requirements definition - System Requirements/ Conceptual Prototype Design, Draft Document
July 1994	Validation testing of prototype - ProMED Phase 2 Conceptual Prototype Software Application and Conceptual Prototype Storyboard, Release 1.1.p (DoD)
November 1994	Productive use of Phase 2 software applications at pilot sites

Phase 3

January 1995	Requirements definition - ProMED Functional Requirements
February 1995	ProMED Phase 3 Functional Requirements, Final
July 1995	Productive use of Phase 3 software applications at pilot sites

Supplemental Deliverables (Provided But Not Required) to be Returned at Project Conclusion

January 1994	Equipment Review and Materials List
August 1994	Implementation Plan
August 1994	ProMED System Test Plan, Phase 2
September 1994	Workflow Diagrams and Benefits Matrices
	Brooke Army Medical Center
	Walter Reed Army Medical Center
	Wright-Patterson Medical Center
October1994	ProMED - DoD Phase 2, ProMED AdminTool User's Guide, Draft

	ProMED - DoD Phase 2, ProMED Newton User's Guide, Draft
February 1995	ProMED Implementation Workplan, Phase 3
March 1995	ProMED System Test Plan, Phase 3
July 1995	ProMED Newton User's Guide, Final
July 1995	ProMED Newton Applications
July 1995	PDA Server & CommGate

2.3 Findings (Qualitative, Quantitative)

Qualitative Findings - Newton Functionality in Phase 1

WP, N=1

BAMC, N=13

In Phase 1, with initial use of the original Newton MessagePad as a personal organizer (using the names, datebook/calendar, and notepad functions), users described the Newton to be convenient and fairly easy to use. One user found the Newton to be so convenient that he replaced his manual, paper-based personal organizer method with that offered as part of the Newton. The overall rating of the original Newton as a personal organizer in Phase 1 on a 1 (poor) to 5 (excellent) scale was average (3.10).

Although users had a positive response to the Newton concept, they also reported:

- Poor handwriting recognition
- Newton's response/processing time to be slow
- Difficulty correcting entries
- Difficulty reading the screen due to glare
- Short battery life

Based on these findings, on a usage scale of 1 (minimal) to 5 (frequent), users rated their degree of use of the Newton to be medium (average use score = 2.78).

With regard to provider-to-provider communications, including line of sight beaming and add-on fax hardware, users rated the communications capabilities to be above average (score = 3.67; scale 1 = poor, 5 = excellent), but indicated its potential usage to be minimal (score = 1.25, scale 1 = minimal to 5 = frequent).

Using the notepad function for rounds, users rated the free text entry function to be average (score = 2.50; scale 1 = poor, 5 = excellent), with projected use to be low (score = 1.75, scale 1 = minimal to 5 = frequent), most likely related to users'

complaints of frustration due to poor handwriting recognition.

Qualitative Findings - Conceptual Prototype ProMED Software in Phase 1

BAMC, N=11

In January, 1994, the ProMED Conceptual Prototype was delivered to the ProMED pilot test sites. The purpose of the Conceptual Prototype was to demonstrate the functionality of the ProMED application software which was to be delivered in Phases 2 & 3.

Conceptual Prototype - Census, Check In, and Patient Demographic

Users thought the Census, Check In, and Patient Demographic functions were easy to use and contained all of the required information (score = 4.14; scale 1 = poor, 5 = excellent). They would like to see all of the patient demographics on one screen, but due to the screen size of the Newton, the use of expandable information banners was felt to be an adequate compromise. The users also complained that there continues to be a handwriting recognition problem and projected "average" use (score = 2.67, scale 1 = minimal to 5 = frequent).

Conceptual Prototype - Ordering (Lab)

The health care providers rated the Lab Orders module to be above average (score = 4.43; scale 1 = poor, 5 = excellent), also with above average potential for use (score = 3.50, scale 1 = minimal to 5 = frequent). Users comments included that the module was easy to use and the test /profile lists were complete and thorough.

Conceptual Prototype - Ordering (Radiology)

Users rated the Radiology Orders module to be above average (score = 4.40; scale 1 = poor, 5 = excellent), with high potential for frequent use (score = 4.67, scale 1 = minimal to 5 = frequent). Users comments included that the module was easy to use and the procedure lists were good.

Conceptual Prototype - Ordering (Order Sets)

Although only two (of eleven) HCPs commented on the Order Sets module , those who responded found the application to be excellent (score = 5.00; scale 1 = poor, 5 = excellent), with high potential for frequent use (score = 5.00, scale 1 = minimal to 5 = frequent). Users again commented that the module was easy to use, but one HCP did not like the concept of order sets, stating, "Universal orders as [with] anything universal always fit everyone poorly." With this in mind, user training would need to include further instruction regarding order sets functionality, including general as well as individual health care provider-defined order sets.

Quantitative Findings - Baseline Patient Wait Time Studies -

Considerations (because of time and resource constraints at the pilot sites not all of these items were explored or measured):

1. The patient wait times were based on either the scheduled appointment times or the actual check-in times, whichever was *later.*

2. When the actual check-in time was later than the schedule appointment time, was the time difference due to the patient's own tardiness or due to a problem at the check-in desk?

3. With time and performance studies such as this, several points must be considered:

   Were there quicker than normal response times because personnel knew they were being timed?

   Were there longer patient visits/exams because HCP knew there were being timed?

4. Possible time study/wait time calculations (in minutes) given the data collected:

   a. Scheduled appointment time or actual check-in time (whichever was *later*) until the time care was initiated [either a patient's vital signs (VS) were taken or the patient was seen by the HCP, whichever came first]

   b. Scheduled appointment time/actual check in time (whichever was *later*) until the time the patient was seen by the HCP

   c. Patient wait time from the point VS were taken and being seen by the HCP

   d. HCP time spent with patient

   e. Entire patient visit processing time (from actual check/scheduled appointment, whichever was later, to the time the patient left the clinic)

   f. Patient wait times - from the time the patient arrived at the ancillary department to the time the patient left the ancillary department [Key question: was the necessary service (medication, lab sample) obtained during this time?].

WP, N=25

A patient spent an average of 38.76 minutes in the pilot site clinic. The individual throughput times were calculated based on either the patient's check in time or scheduled appointment time, whichever was later, until the time the patient left the clinic.

In the baseline time study, health care providers spent an average of 25.48 minutes with a patient. This time measurement is particularly important to examine post-ProMED implementation to see if the use of ProMED enables HCPs to spend less

time with performing administrative functions in order to have more time for other things, such as quality time with an increasing number of patients. Although the collected information presented here is useful, it may be more beneficial to further investigate the HCPs' time spent with a patient based on the patient's diagnosis.

Patients spent an average of 15.38 minutes waiting in pharmacy for prescriptions (N=8) and 15.00 minutes at the laboratory to have lab specimens collected (N=2), while a patient waited 32.00 minutes in radiology to make an appointment. If post-ProMED Implementation data was available, it would be expected that the ProMED modules including, pharmacy, lab, and radiology orders, along with the order sets and write in modules, would:

- decrease patient waiting times, potentially increasing patient satisfaction
- increase HCP and ancillary staff's efficiency/productivity in accurately entering and completing orders
- provide multiple points of access to patient information via the Newton, rather than solely through the patient's chart.

Quantitative Findings - Post-ProMED Implementation

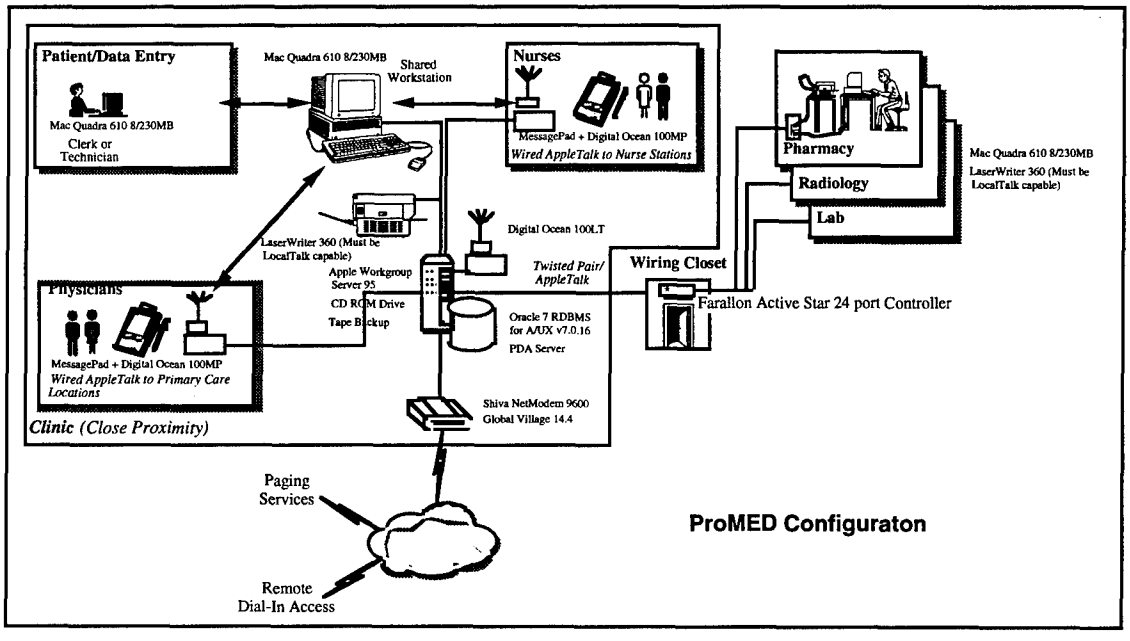
When using ProMED to order his typical drug of choice for a patient with a urinary tract infection, one particular physician noted the cost of the medication to be approximately $21.00 for a course of treatment. ProMED's cost display feature also offered an effective, less costly alternative medication at $.80 per course of treatment. Not realizing the significant cost difference until this instance, the HCP verified the finding with the hospital's pharmacy. As a result of ProMED's cost of medication/treatment screen display feature, the physician changed his medication ordering patterns to the less costly alternative drug, ultimately reducing the cost to the institution.

2.4 Technology

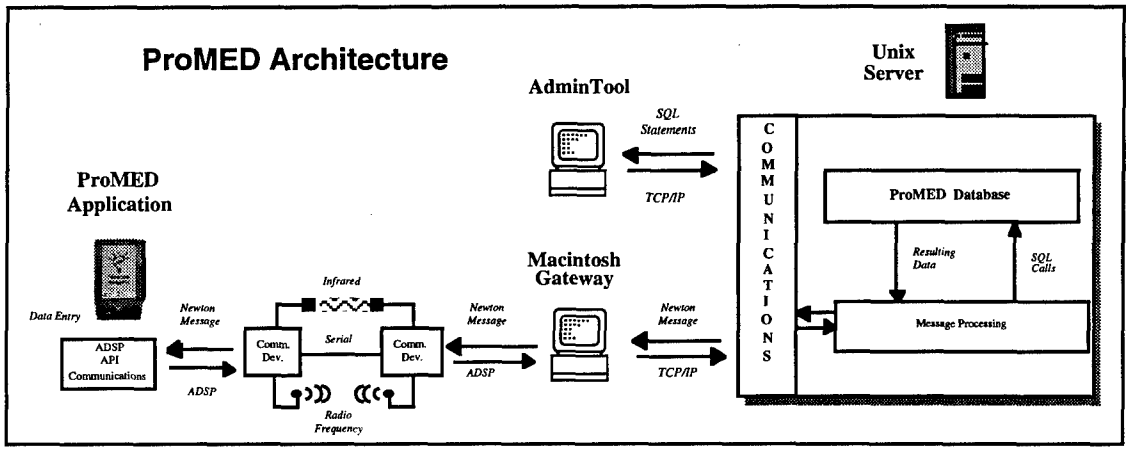
This section discusses the technology used in ProMED development to evaluate the use of mobile, handheld computer technology in the DoD. Paragraphs in the section describe the technical architecture and approach of the ProMED pilot project.

2.4.1 Technical Architecture

This section describes the technology used to implement ProMED. The following diagram illustrates the final technical configuration of the pilot project. It is a graphical representation of the components described in this section and shows the interconnection between the components.



The next diagram illustrates the final technical architecture of the ProMED solution. It is a high level diagram depicting the communications that take place between the various components of ProMED.



The following paragraphs describe the individual components of ProMED.

Newton

The Apple Newton MessagePad and its communications add-ons are the most visible pieces of ProMED. As the primary user interface for the Health Care Provider user, the Newton provides services for downloading and viewing patient data, loading site-specific data, and uploading patient orders to the server.

Newton hardware consists of the following:

- Apple Newton MessagePad 100 and MessagePad 110
- Apple Newton 4MB flash storage
- Digital Ocean 100MP wireless LAN transceiver

Newton software consists of the following:

- Newton Operating System 1.05 (MessagePad 100)
- Newton Operating System 1.3 (MessagePad 110)
- KPMG ProMED Census 1.1b6
- KPMG ProMED Chart 1.1b6
- KPMG ProMED Orders 1.1b9

- KPMG Load ProMED 1.1b7

Wireless

The wireless component of ProMED provides the mobile communication link between the Newton MessagePad via connection to a wireless LAN. Wireless hubs are connected by serial cable to the ProMED server and have an approximate range of 4000 square feet each.

The wireless LAN consists of the following:

- One or more Digital Ocean 100LT groupers
- One 100MP grouper per Newton

Communications and Database Server

The ProMED Communications and Database Server is the primary data store and central point of control for communications between the PDA devices, workstations, and the database. All data relative to health care providers, patients, sponsors, orders, and carotid artery duplex studies is stored on the database and available for query and/or update. Additionally, all wireless communications are routed to the server where they are translated and sent to the database engine for processing. Server features include auto-start/auto-restart capability for ease in resetting the server and dial-in access to allow remote administration of the server and database.

Server hardware consists of the following:

- Apple Workgroup Server 95 with 48MB RAM
- 230MB hard disk drive
- 1GB hard disk drive
- CD-ROM drive
- DDS-DC 4mm tape backup drive
- Global Village TelePort Gold 14.4 kbps modem

Server software consists of the following:

- Apple A/UX 3.0.2 operating system
- Oracle 7.0.16 Server for A/UX
- SQL*Net TCP/IP
- KPMG PDA Connect
- KPMG PDA Server
- Dantz Development Retrospect Remote

Workstations

Macintosh workstations function as administrative terminals. These terminals are used for entry of patient, sponsor, and provider data into the ProMED database and for making patient-provider assignments. Additionally, one workstation serves as the print server to support the printing of orders at the appropriate ancillary department. Workstations are connected to a LocalTalk network via the built-in AppleTalk communications protocol.

Workstation hardware consists of the following:

- Macintosh Quadra 610 with 8MB RAM
- 230MB hard disk drive
- LaserWriter 360 laser printer

Workstation software consists of the following:

- KPMG ProMED AdminTool 1.0a10
- Oracle Card 1.1
- Oracle Reports 2.0 (Print server only)
- AppleScript 1.0 (Print server only)

Integration

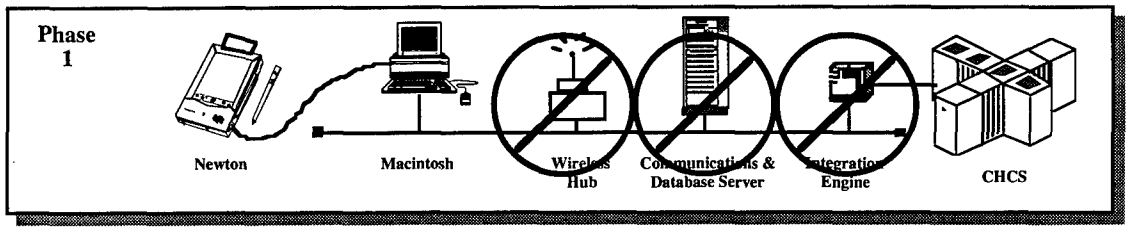
ProMED also has the capability to load and use data generated by the legacy systems at two of the ProMED test sites, WRAMC and Wright-Patterson, via a set of integration tools. These tools, which are run nightly on the ProMED server, read data from a file generated by the legacy system and load the data into the ProMED database. The tools provide a means of automatically adding and updating patient and sponsor information in the ProMED database, assigning providers to patients, and retrieving patient test results.

2.4.2 Approach

This section discusses the approach to the technical development used in the ProMED pilot project. Following is a description of each phase of the project.

Phase 1 - Concept Introduction

Phase 1 involved the introduction of the Newton device to health care providers (HCPs) at the pilot sites. The primary goal of this phase was to familiarize the HCPs with the Newton and to have the Newtons function as a personal productivity tool in note taking, appointments, scheduling, and name tracking.



Following are the task descriptions, highlights, and issues that comprised the technical components of Phase 1.

General

- Newtons and Newton Connectivity Kits were delivered to the pilot sites. A Newton Boot Camp training session was conducted by KPMG at each pilot site to teach the HCPs the Newton basics.

- Technology at the existing sites was inventoried, a technical baseline was established, and site-specific technical requirements were presented.

Newton

- A functional prototype of the ProMED Apple Newton user interface was developed to demonstrate its potential use as a health care application, to stimulate ideas for the pilot application design, and to build a re-usable code base for future applications.

Technical Architecture Development

- The preliminary strategy for the Newton ProMED architecture development was defined. This approach allowed for sharing of objects between potential packages enabling packages to operate independently or with other packages of the same product family.

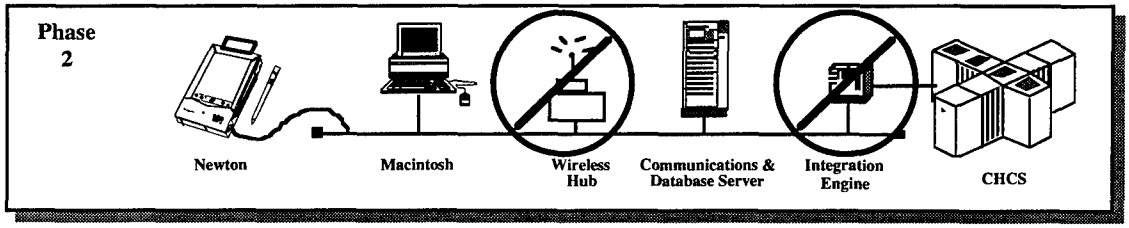
- Research was conducted to identify alternatives for Newton to database server connectivity. Investigation of all alternatives found that no commercial connectivity products for the implementation of client/server based Newton™ communications were available at the time. This necessitated our development of a Newton™ communications server independent of any commercial products, i.e., "from scratch".

- Impact on the CHCS enterprise system at Walter Reed Medical Center and Wright-Patterson Medical Center was considered. Though it is clear that long-term success of Newton utilization in health care facilities throughout DoD is in part dependent upon interfacing with the CHCS enterprise system, at this stage of the project, a decision was made to defer development of such an interface beyond the current ProMED project.

Phase 2 - Concept Demonstration

Phase 2 of ProMED involved implementation of the initial ProMED system. The initial implementation featured complete patient record processing and limited order processing via a tethered Newton. The ProMED Communications and

Database server and the ProMED AdminTool were also installed during this phase. The emergence of the server allowed the Apple Newton to seamlessly access patient, provider, and sponsor data in the database. The AdminTool allowed the addition and maintenance of patient, provider, and sponsor data. The health care provider could now perform daily downloads of his/her patient demographic data, write pharmacy, lab, imaging, and nursing/clinic orders, and print orders to any printer on the network.



Following are the task descriptions, highlights, and issues that comprised the technical components of Phase 2.

Newton

- The Newton user interface conceptual prototype was developed.

- Development was completed on the Newton components of Phase 2 applications. This effort included some re-tooling of previously completed work to account for the difference in screen size between the original Newton MessagePad and the newly-released MessagePad 110.

Technical Architecture Development

- The communication architecture to support the ProMED applications was designed and developed. This included the communications gateway (CommGate), Newton to Server protocol, software architecture, and database services.

  During implementation of the Newton communications architecture to support the ProMED server, we encountered bugs in the ADSP implementation by Apple. This required that we slow down the transfer of data to the Newton as a work around for the current limitations of the Newton ADSP implementation.

- Initial equipment requirement recommendations were made to implement the delivery of Phase 2 functionality.

- Research of wireless technologies was conducted based on the architectural approach of the ProMED server.

Communication and Database Server Design and Development

- Investigation into several possible server implementation architectures was conducted.

- A version of the ProMED server was completed that was compliant with Phase 2 requirements. The server has been designed to support expanded functionality for

Phase 3 and subsequent phases of the project. Development of the server included the design and development of the CommGate, ADSP to TCP protocol converter required for the Newton to Newton server communications, communications services, database services and the installation and configuration of the Oracle database.

- A data model for the ProMED database was developed. Though data models were currently in place and being used on the legacy CHCS system, they were not easily adaptable for the Newton application. ProMED, as with most mobile applications, require data models that reflect the end users' point of view, which the legacy data model is not.

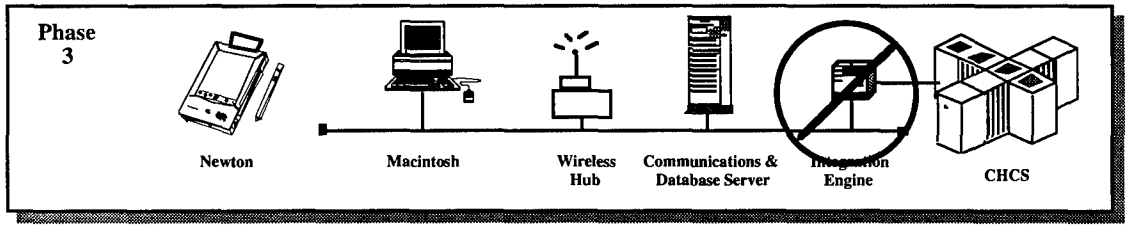
- The Oracle database was selected and database access routines required for Phase 2 functionality were written using Oracle development tools.

Administrative Tool Design and Development

- The ProMED AdminTool was developed to aid in entering patient, provider, and sponsor data until integration with the CHCS system took place. Development of the tool was necessary to provide a means of manual data entry in the absence of an electronic interface.

Phase 3 - Concept Validation

Phase 3 of ProMED was the final phase of the project and involved the completion of the ProMED application and the addition of wireless communication capability to the Newton units. Completion of the application meant that the health care providers could submit an order and have the order print on the correct form at the appropriate ancillary department(s) without manual intervention. The provider could also view and alter any previous orders that had been entered for the patient. Certain test results (Carotid Artery Duplex) were also available for viewing. The addition of the wireless component to ProMED allows HCPs to download data and submit orders without the requirement of a wired connection.



Following are the task descriptions, highlights, and issues that comprised the technical components of Phase 3.

Newton

- The application scope and Newton user interface design for Phase 3 were finalized and the ProMED Newton application was completed.

Technical Architecture Development

- A CHCS/ProMED interface was designed, developed and installed at Wright-Patterson Medical Center to allow the electronic transfer of patient demographic and provider assignment data between the two systems.

- Additional system components were designed and developed to support the Carotid Artery Duplex Study functionality required for WRAMC, including ProMED/FileMaker Pro interface for patient data, Newton client application design and development, and database services.

- Oracle Reports 2.0 was selected as the tool for development and implementation of the orders reporting functionality.

- Developed Phase 3 applications, including Newton client applications, database and communications services, and administration and reporting tools.

Communications and Database Server Design and Development

- ProMED server was enhanced to meet Phase 3 requirements. Development of the server included the design and development of the CommGate, ADSP to TCP protocol converter required for the Newton to Newton server communications, communications services, database services, and the installation and configuration of the Phase 3 Oracle database.

Wireless Implementation

- The Digital Ocean wireless LAN technology was tested and selected for Phase 3 activation.

- Preparation and deployment of wireless communications system were made, including site assessments and coverage mapping for each pilot site, equipment definitions, facility requirements, system configuration, and user training.

- The wireless equipment was installed and tested at each of the three pilot site.

2.5 Obstacles

During the course of the engagement many unforeseen obstacles were encountered which had a significant impact on the course and outcome of the project. These obstacles were beyond the control of KPMG Peat Marwick and affected either the project schedule, the degree and breadth of system utilization and evaluation , and/or the composition of deliverables. The major impediments were:

- Hardware and System Software Delivery
- Lack of Required Site Resources
- Absence of a Newton-Server Communication Driver
- Change in Project Management Team at BAMC

- Lack of Communication Network at BAMC
- Failure of the Sites to Complete Assignments

2.5.1 Hardware and System Software Delivery

Initially, the ProMED DoD project office had difficulty finding the needed funds for the purchase of the hardware and software. Configuration requirements for each site were finalized late February but the hardware did not arrive at either KPMG Peat Marwick or the pilot sites until mid-April for configuration and testing. This delay of several months negatively affected the balance of the project schedule. Thus, software delivery and installation and system implementation and activation for Phase 2 and Phase 3 were accordingly delayed. The ultimate result was the reduction in time of system use and the minimization of findings and opportunity for analysis.

2.5.2 Lack of Required Site Resources

During the initial planning for the ProMED project it was determined that each site would have, at a minimum, a part-time person dedicated to performing certain important administrative functions including patient registration and provider assignment. In addition, this individual would assist with the development of ProMED policies and procedures and be responsible for collecting evaluation data. The hiring of these local data entry clerks never occurred at any of the sites in a timely fashion. Only Wright-Patterson Medical Center complied with this requirement but this occurred very late in the project (July) and had little impact on their ability to effectively support system usage and project analysis.

2.5.3 Absence of Newton-Server Communication Software

When the Apple Newton was originally released there was no communications software which would allow the Newton to communicate with a host server. To provide the user with the ability to upload data (orders, vital signs, etc.) from the Newton to the server and download data (order numbers, patient census and demographics, duplex studies) from the server to the Newton, customized communication instructions/applications had to be developed by KPMG Peat Marwick which included:

- Software to execute on the Apple Newton to support the uploading to and downloading from the server.

- Protocol conversion software, CommGate, to convert messages from Apple format to TCP/IP and interface to the UNIX operating system, and Newton PDA Server.

- Software to run on the server to convert Newton messages into SQL for writing to the Oracle database, and convert retrieved data to Newton messages.

KPMG Peat Marwick expended eleven work months to develop these customized

application programs. If this communications software had existed prior to the start of the project, these 11 work months could have been devoted to developing and writing ProMED functional application programs.

2.5.4 Change in Project Management Team at BAMC

Several months into the project the Director of Management Information Systems at Brooke Army Medical Center (BAMC) was transferred and a new Director was assigned as a replacement. With this change in information systems management, much of the momentum was lost and the project team had to adjust their activities as a result. In addition to the transfer of the Director of Information Systems, the ProMED site champion at the Troop Medical Clinic (TMC), LTC Karen Paris, retired and was replaced with CPT Robert d'Angelo. Although, the impact of this change was less significant, this event only added to the existing level of project discontinuity.

2.5.5 Lack of Communication Network at BAMC

For the installation of Phase 2 software each site was required to have installed a wired PhoneNet/LocalTalk local area network. This was never accomplished at the Troop Medical Clinic during the duration of the project. Without such a network the ProMED users had no way of accessing the server and performing the required download and upload of data. Only near the end of the project was a limited wireless network installed which allowed BAMC to simulate the productive use of Phase 2 and Phase 3 ProMED applications. As a result, little quantitative or qualitative data was obtained from BAMC for the study.

2.5.6 Failure of Sites to Complete Assignments and Expand Use

During the course of the ProMED project, the KPMG Peat Marwick team provided the sites critical time-sensitive assignments, including but not limited to:

- Review and verify the site workflows
- Complete cabling for local area network
- Review and provide additional input to evaluation and benefit matrices and baseline measurement criteria
- Complete evaluation forms for each phase of the project
- Complete sign-off forms for each major task of the project
- Add additional users once software was stable.

Without these tasks being completed on a timely basis it was difficult to collect the necessary data to conduct a thorough analysis, particularly related to quantitative measurements.

3 Conclusions

A careful review and assessment of the results of the project would lead one to conclude that ProMED was successful. Satisfaction with the project was particularly noted by Paul Zimnik, DO, ProMED Project Manager, in an August 1, 1994 letter (see Appendix) to Mr. Bob Whitecotton of Apple Computer, Inc. In the letter, CPT Zimnik wrote that the Department of Defense (DoD) was "pleased with the project" and that the project "has been successful in demonstrating the feasibility of using hand held device technology" in the DoD medical information management environment.

In this section of the ProMED final report, conclusions derived from the project are presented. These conclusions focus on two key areas:

- Discoveries and Lessons Learned
- Recommendations for Future Work

3.1 Discoveries and Lessons Learned

The use of Personal Digital Assistant (PDA) technology in the form of the Apple Newton in the health care environment was shown to offer important value to care givers. User assessment of the PDA technology and the applications that were developed as part of the ProMED project was very positive and user acceptance was very high. The principle findings and conclusions of this study fall into the following categories:

- Mobile, Wireless Communications
- Portability of the Newton MessagePad
- Performance Measurements
- ProMED Development Environment
- Site Workflows and Benefit Matrices
- Robustness of the Application Software
- Handwriting Recognition and Use of Forms Data Entry

3.1.1 Mobile, Wireless Communications

The major milestone and breakthrough of the project which led to the overall success of the project and the validation of the usefulness of PDAs in the health care environment was the installation and implementation of wireless data communications. Col Jeffrey Roller of Wright-Patterson Medical Center commented that it opened up a whole new universe to him. Users were no longer tied to a wire and access with the system could now occur from any spot within the wireless network. This portion of Phase 3 showed that one of the keys to the entire project was the ability to provide the user with mobile and wireless communications.

3.1.2 Portability of the Newton MessagePad

The Apple Newton MessagePad is a truly portable device. It is small and compact and weighs less than 2 pounds. The size of the unit allows it to be easily carried in the pocket of a provider's lab coat. As a portable device, users can take it with them anyplace in the institution and access the baseline Newton functions (Names, Dates, etc.) as well as patient medical functions such as patient census. This portability lends itself very well to the mobile practices of a physician in a medical facility, though the use and application of PDA technology is not limited to physicians.

3.1.3 Performance Measurements

The Newton MessagePad is not a particularly fast device. Screen changes between functions and modules were initially noted to be relatively slow. Experienced automation users especially complained about a long, delayed transfer time, a sure indication that enhancement of the Newton's performance should be a major focus of future development. It was also noted that the rather short battery life (less than 16 hours of continuous use) was unsatisfactory and limited its usefulness. The power supply was changed in the new MessagePad 110 and greatly improved battery life (better than a 50% increase with continuous use) and added to the value of Newton in the health care environment.

3.1.4 ProMED Development Environment

The development tools and methodology employed for the development of the Newton applications proved to be very effective and efficient. Once the user functional requirements and specifications for an application had been defined (using standard requirements definition and development tools), the translation of these requirements into software was relatively quick. With object oriented development, the software was rapidly developed and tested (unit, module, system), bugs and deficiencies in the code corrected, and final testing performed. The speed and efficiency with which application software was produced with Newton proved to be one of the enriching aspects of the project and far superior compared to traditional development environments.

Newton Toolkit (NTK) was the development environment used to develop the Newton applications. NTK was not in production during most of the initial Newton user interface development, and a beta version was used in its place. As a result, KPMG developers' efforts were slowed due to the need to find workarounds to the bugs inherent in the beta release. However, when the production version arrived, developers realized great gains in application development time. NTK proved to be a stable development environment and was well received by all who used it.

The real challenge to the ProMED development was in providing access to patient information and order submission to the ancillary departments. As stated earlier in the report, this required development of custom communications software for the Newton as well as the development of communications, session management, message translation and processing, and database access on the Newton PDA server. Refer to section 3.2.4 for a more detailed description of the development

and development environment.

Development experience with Oracle Card, which was used to develop the AdminTool, showed it is a satisfactory prototyping tool and met the needs for developing a quick front end application for accessing ProMED data. Although it met the short-term needs of the project, it is probably not viable for a long-term solution, and use of this tool for follow-on ProMED projects should be reconsidered. Problems were encountered during coding and system generation, notably in the development environment. In dealing with the vendor for resolution, it did not appear that the product would be supported or maintained in the future.

3.1.5 Site Workflows and Benefit Matrices

One of the tasks performed for the ProMED project was to develop workflows of the ordering procedures for the three major ancillaries - Laboratory, Radiology, and Pharmacy at each of the sites. These workflows (see Appendix) document both current and proposed procedures and depict all current data and information flow and operational processes as established to support orders in the respective facilities. These workflows were very useful in documenting the operational change at each site as a result of the implementation of the ProMED modules. These workflows were validated with each of the site representatives.

The Benefit Matrices (see Appendix) were also individually developed for each institution and were provided to each of the site champions. These matrices outline areas for both quantitative and qualitative benefits the site could potentially expect and realize with full implementation of the ProMED modules. Each site was requested to review its own matrix and assess and measure the impact of the system on the department's operations and procedures. With this confirmation of ProMED function and benefit, DoD approval for additional Newton development could be more easily justified and obtained.

However, for several reasons, documentation of quantitative findings was minimal. Of note, the following observations are offered:

- Walter Reed Army Medical Center decided only to simulate the ProMED functions in an inpatient setting since without a CHCS interface for order entry it would have increased the amount of work for the participating physicians;

- Due to the delay in acquiring and installing the required hardware, ProMED was not implemented at Brooke Army Medical Center until mid-July and then only in a small simulation environment;

- Wright-Patterson Medical Center was able to experience ProMED in a limited production capacity and clearly demonstrated its effectiveness; the assessment process was short-lived in the latter stages because a key participant of the study was placed on TDY for an indefinite period of time.

3.1.6 Robustness of the Application Software

When the ProMED application software was delivered to the sites, users were asked to assess and evaluate the utility and robustness of the application software.

The users were very enthusiastic about the level of the functionality and general ease of use with the applications. Users also stated that the flow of information and data and screen design and formats within the ProMED modules were logical and easy to follow and understand. To validate and confirm the user friendliness and ease-of-use, most users needed less than thirty minutes of training in order for them to effectively navigate through the ProMED Newton functions. The user interface is simple, easy to understand and use, and highly compatible with the naturalistic behavior of the user.

3.1.7 Handwriting Recognition and Use of Forms Data Entry

One of the initial heralded features of the Newton MessagePad was its handwriting recognition capability and its ability to convert handwriting into ASCII equivalent characters or text. This was one of the features of the Newton which captured peoples' imagination and made it an ideal technology for use in a health care environment. As the ProMED project evolved and the collective experience with the Newton increased, it became obvious that the Newton fell short with this function. A sophisticated user who spends a great deal of time documenting data, as physicians and nurses do, would find the Newton handwriting recognition function deficient and constraining and they would quickly abandon its use. With this in mind, an alternate and more efficient method of data capture and data entry had to be developed that did not so completely depend on the recognition and conversion of handwriting.

The answer was forms data entry. Input screens which very closely resembled current paper-based systems were designed and incorporated into the ProMED applications. This accomplished three principle objectives, namely (1) users were presented with a form on the Newton that was familiar to them, increasing the acceptance of the system and decreasing the amount of time required for user training and education; (2) this was consistent with current operations; and (3) form data entry was easy and efficient because users simply had to click on choices with minimal dependency on handwriting recognition. The Newton has proven to be a very useful tool on which to design and develop forms based data entry. Clearly, this is one of Newton's strengths and should be exploited in future applications.

3.2 Recommendations for Future Work

The collective experience of the ProMED participants, knowledge gained, and lessons learned have carefully revealed areas of opportunity for future development and of PDA-based solutions in the DoD health care environment. These areas of opportunities are present below as recommendations and are prioritized in decreasing order of importance, as follows:

3.2.1 Apple Newton Performance

The performance of the Apple Newton 100 and the second generation Newton 110 were examined.

Initial assessment by users of the original Newton indicated the device was slow

and cumbersome. Several areas of performance were investigated.

- Module Transfer: Transfers between modules of ProMED could take as long as 15 seconds. To a sophisticated or demanding user such as a physician, that is a very long time to wait for transfer to a different module. Many users expressed frustration at the slow transfer times on the Newton.

- Census Check-in: Downloading of patient census, demographic, and order data to the Census and Chart modules was assessed. Check-in times generally ranged from 20 seconds to as long as one minute with the average being about 35 seconds. The variability of this process is dependent on the size of the user's census - the more patients assigned to a provider and downloaded from the server to the Newton, the longer the process.

- Order Submission and Printing: The design of the system in Phase 3 allowed a user to submit an order or order set and have the ProMED server correctly route the orders to the appropriate department and printer. This process, mainly due to hardware restrictions and performance limitations on the Newton, would take as long as four minutes from the start of the job to the completion of the printing at the departmental printer. Although this time lag has no effect on users or user acceptance of the system, this delay could impact patient care and satisfaction through longer service times in the ancillary areas.

The Newton proved to be fairly limited in memory capacity, processing power, and communication capability. However, the real value of the Newton is it's ability to access and display information stored on other larger computer systems. If the Newton is to be totally accepted and embraced by clinical users as a computing and communication device, its performance and speed have to be improved and more extensive communications features must be added. For future work in ProMED or other health care applications, this should be a principle focus of research and development by Apple Computer, Inc.

3.2.2 Wireless Communications

Very early in the project it was apparent that tethered communications via PhoneNet and LocalTalk did not offer the preferred, long-term communications solution for ProMED. An investigation was initiated to explore existing third-party wireless technology on the market. This search led to Digital Ocean which offered a proven wireless solution using RF Spread Spectrum technology.

The installation of the wireless portion of the project was deemed by the users to be an essential component of the project. With the Digital Ocean equipment and wireless communications, users were free to roam the clinic and ward areas untethered and unencumbered. After the implementation of the wireless portion of the project, response from the study participants was unanimously positive. The only negative cited by the study participants was the weight and size of the Digtial Ocean hardware.

While Digital Ocean's wireless solution received positive user feedback, it did have technical limitations. The biggest limitation is that each Digital Ocean device (Grouper) can be configured to communicate with exactly one hub. Each hub has a limited range, and as a result, users are confined to the area of the hospital served

by the hub for which their Grouper is configured. Each hub also has a maximum capacity of 15 connections, further constricting user activity. (Future releases from Digital Ocean promise to eliminate these problems.)

While Digital Ocean's solution was a good fit for the ProMED pilot, any future projects should be aware of the latest developments in Newton communication technology. At the time that the wireless investigation took place, few commercial vendors were bringing Newton wireless communication solutions to market, and of those, even fewer were mature enough to be of value to the project. The ideal ProMED solution would allow any reasonable number of HCPs to connect from anywhere in the hospital, and as Newton communication technology evolves, other wireless solutions should be evaluated and considered to achieve this goal.

3.2.3 Interface with Composite Health Care System

It was clear from the very beginning of the project that for the ProMED applications to be fully functional and robust and add incremental value to information use and management, an interface with the hospital enterprise system [Composite Health Care System (CHCS)] was essential. As requested by DoD project management, a comprehensive CHCS interface was not developed for ProMED. Along with wireless communications this is critical to the usefulness of PDAs in the health care environment.

With an interface, patient data would transfer from CHCS to ProMED on a real-time basis. Candidate data for this CHCS download would be patient census data, demographic information, order data (order numbers), and results from Laboratory, Radiology, and other reporting departments. Data which could be uploaded from the Newton to CHCS would be orders to the appropriate department and patient clinical data (vital signs, history and physicals, I&O, etc.). In such a scenario, CHCS would receive the information from ProMED and execute the order or store the information in the appropriate patient record. This would allow the DoD hospitals to continue their use of CHCS and additionally maximize the use and strengths of the Newton and ProMED.

3.2.4 Technical Architecture

The design, development, and eventual implementation of the ProMED technical architecture involved the integration of many different platforms into a single working system. The effort was not trivial. In several instances devices or products which were not originally designed to communicate with each other had to be integrated and the resulting solutions had to be flexible enough to support future extensions. The following paragraphs describe some of the issues and recommendations that grew out of this effort.

Because of the lack of a commercially available Newton connectivity solution which was mature enough to meet the requirements for this pilot project, development of a custom communications server was necessary in order to allow the Newton to access the patient records in the ProMED database. This proved to be a tedious, timely, and costly venture, though it yielded a product far superior to the solutions available at that time.

KPMG's objective was to design an open, flexible communications solution that could be easily enhanced as the ProMED system grew. As such, design decisions involved several considerations.

- The solution had to support the native Newton protocol, yet still remain open. Thus, an ADSP to TCP translator was written into the server code.

- The server's architecture had to be extendible. We opted for an object-oriented design to which we could easily add protocol support and extended service options - SQL, RPC.

- The solution had to be portable and accessible from a variety of different platforms, a requirement easily satisfied by implementing the server using TCP/IP on a Unix-based machine. We chose A/UX, Apple Computer, Inc.'s version of Unix, as our development platform in part because of our relationship with Apple Computer and in part because of cost considerations.

The KPMG development staff spent a considerable amount of time wrestling with other idiosyncrasies and limitations of the A/UX operating system. The development environment is neither well documented or adequately supported. One example of the poor support is that during the course of development several compatibility problems were witnessed between A/UX and the Oracle database software. After consulting with Oracle support personnel to no avail, the development team was forced to downgrade from the current A/UX 3.02 operating system to A/UX 3.01. Although this was a viable short term solution, it was a reflection of the low priority which Oracle and potentially other third-party vendors have toward supporting the A/UX platform. From a development standpoint, a Unix platform with a very robust development environment, adequate user support, and a large software base would provide a better foundation for any future ProMED server or CHCS gateway projects.

That is not to say that use of A/UX was a poor fit for the ProMED pilot; using A/UX did benefit the project by keeping software and hardware prices down. The operating system itself is inexpensive relative to the cost of other Unix-based operating systems. Also, the Oracle database server software for A/UX was nearly half the cost of the same product for other Unix-based operating systems. Free Software Foundation's Gnu C++ development environment was available for the A/UX platform, sparing the expense of purchasing one. Further cost savings were achieved through the A/UX Macintosh desktop interface, which allowed the KPMG PDA Server software to run on an A/UX machine instead of requiring an additional Macintosh to act as the PDA gateway.

Also, other recently-released middleware products should not be overlooked. Several Newton connectivity solutions, such as Wayfarer's Newton Server, have emerged since the beginning of the ProMED project. While these solutions were either immature or non-existent at ProMED's time of need, many of them have grown into excellent products and should also be considered.

Difficulty was also encountered in moving data between the ProMED database and the Newton. The problem is that the formats which the Newton and Oracle used to store data are radically different. The Newton stores data in object-oriented data soups, while the Oracle relational database stores data in tabular format. No commercial products existed to allow the two products to exchange information, so developers had to build an algorithm into the communications server which

converted data in the soups into a format usable by the database code. Though this solution worked well, it has a fairly large impact on the performance of the data transfer between the Newton and the database. Performance gains could be realized by either the addition of an object store on the server or an SQL translator on the Newton; as such products become available, they should be evaluated and considered.

Oracle Card, as mentioned above, proved to be a satisfactory prototyping tool for the short-term. However, because of the various problems encountered in its use and because it does not appear that the product will be supported or maintained in the future, other graphical user interface (GUI) development tools should be investigated as options for future projects.

3.2.5 Other Potential Newton Applications in Health Care

The Apple Newton has many applications in the health care environment which were not explored in the ProMED project. The additional applications listed below would be ideal candidates for future design and development within the DoD health care community, however, this does not represent an exhaustive list.

- Case Management: Define the types of cases the institution would like to track (normal criteria are high volume, high risk, and high cost) and establish for each case the associated critical pathway and the components for each pathway. The Case Managers would have a list (census) of patients for whom they are responsible and on a daily basis would assess the patient's progress and chart it on their Newton. This data could be uploaded to a database application (usually running on a stand-alone desktop computer) where trending analysis could be performed and compared within the institution and against national standards.

- Charge Capture: With the DoD going to reimbursement, a system of charge capture based on ICD-9 and CPT4 codes is essential. These codes could be mapped to each specialty and when a diagnosis is made or a chargeable procedure is performed, the user would tap on the appropriate code to generate the associated charge and subsequently and automatically post the charge to the patient's account.

- Materials Management: Stocked items for a clinic or Nursing Unit could be defined and loaded onto the Newton. The user would conduct an inventory of the clinic items with the Newton. At the completion of the inventory, the inventory data is uploaded and stock pick lists for each clinic or unit are printed. The clinic or unit is replenished and the department is automatically charged for items restocked. Receivers of shipments could check off receipted items from an order, upload the receipt data, and have automatic verification and payment.

- Medication Administration Record and Intravenous Administration Record: Pharmacy profiles for scheduled and non-scheduled (PRN) medications and intravenous (IV) solutions could be downloaded to the Newton. The medication nurse, when making rounds, could annotate the administration of a drug or an IV. The transaction could be automatically user and date and time stamped by the Newton. This application would be synonymous to the manual MARs and IVARs currently used in most hospitals.

As the Newton and wireless technology evolves, the ultimate benefactor will be the

end user. Form factors will be smaller and more compact and processing speeds will increase. These advances bode well for the ProMED user community. Benefits from this evolution include expanded functionality, larger databases, faster processing speeds in a wireless mode, and off-site access from a user's car, office, or home. These will only increase the utility and value of ProMED and render it an even better resource for the user.

4 References

Two primary references were used in conducting the Project ProMED research. These materials were used to add structure to the system development process and support the clinical requirements documentation process. These two references are proprietary to KPMG Peat Marwick.

Exhibit 4.1 **System Development Life Cycle Methodology (SDLC)**

Exhibit 4.2 **Clinical System Functional Requirements (Templates)**

DEPARTMENT OF THE ARMY
US ARMY MEDICAL RESEARCH AND MATERIEL COMMAND
504 SCOTT STREET
FORT DETRICK, MARYLAND 21702-5012

REPLY TO
ATTENTION OF:

MCMR-RMI-S (70-1y) 21 Apr 97

MEMORANDUM FOR Administrator, Defense Technical Information Center, ATTN: DTIC-OCP, Fort Belvoir, VA 22060-6218

SUBJECT: Request Change in Distribution Statement

1. The U.S. Army Medical Research and Materiel Command has reexamined the need for the limitation assigned to technical reports written for Cooperative Agreement Number DAMD17-93-V-3015. Request the limited distribution statement for Accession Document Number ADB211247 be changed to "Approved for public release; distribution unlimited." This report should be released to the National Technical Information Service.

2. Point of contact for this request is Ms. Judy Pawlus at DSN 343-7322.

FOR THE COMMANDER:

for Gary R. Gilbert
GARY R. GILBERT
Colonel, MS
Deputy Chief of Staff for
Information Management

Completed 1-10-00